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PRODUCTIVITY OF DIVERTED CROPLAND

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Washington, D.C. 20250 April 1969

SUMMARY

Estimates of the average productivity per acre of cropland diverted from production under U.S. Government programs--nearly 63 million acres in 1966--have varied widely. Those concerned with future food and fiber requirements and the Nation's capacity to meet these necessities need a dependable estimate. This study undertakes to meet that need.

The average productivity per acre of cropland diverted in 1966 was estimated at 80 to 90 percent of the average productivity per acre of the cropland in production. This estimate of relative productivity was based on a study of two sources of variation: (a) An intrafarm differential, which exists because fields within a farm have varying levels of productivity and (b) an interlocation differential which exists because the general level of productivity changes from one area to the next.

A formal analysis, which used measurable factors only, showed that the intrafarm difference (diverted acres less productive than cropped acres) was less than 4 percent; the range was from about 1 percent in the Lake States to about 7 percent in the Southwest States. It was estimated, however, that the total intrafarm effect might be about twice the differential found in the formal analysis if all factors were considered.

A second analysis was employed to estimate the location effect of the diverted acres. It was found that proportionally greater diversion was associated with areas having below-average yields per acre. Thus, in aggregate, there was a significant location effect to add to the intrafarm effect. Except for wheat, the location effect accounted for a substantially larger component of the existing difference than the intrafarm effect.

The combined effects showed that acres diverted from wheat were about 90 percent as productive, on the average, as acres producing wheat in 1966. The parallel figure for grain sorghum was 85 percent; for barley, 83 percent; for corn, 82 percent; and for cotton, 80 percent. In arriving at these percentages, we assumed that acreage diverted under the annual program would return to the "designated" crops from which they were diverted. We further assumed that land coming out of long-term retirement would grow these five crops in the proportion specified for annual diversion. About one-fourth of the acreage in diversion during 1966 was diverted under a long-term program.

That portion of the intrafarm difference which could be formally measured was estimated through multiple regression analysis, using the projected yield index of several field crops as the dependent variable. The solution of the regression equation provided coefficients of correlation between the projected yield index and each of several explanatory variables.

In the first phase of the intrafarm analysis, a series of regression equations were solved to find a "best fit" equation that would explain productivity of land used

for crops in 1966. The coefficients generated by that stage were used in the second phase to estimate the productivity of diverted land. The ratio of yield index of diverted acres to yield index of land in production indicated the relative productivity of the diverted acreage.

Potential yields of different lands were distinguished by variables based on the land-capability classifications developed by the U.S. Soil Conservation Service. For each sample county, the relative proportion of cropland in each official land class was entered as a continuous variable in the regression equation. Two sets of proportions were developed. One set was for land in production; the other was for land in diversion.

Data on land use and land capability were obtained from a recent National Conservation Needs Inventory in which the Nation's cropland is divided into 13 subdivisions (see appendix A). In this study, the first four subdivisions were used to represent cropland in production in 1966, and subdivisions 8, 9, and 12 to represent cropland diverted the same year.

Without diversion programs, nearly all annual diverted acreage would return to production. Some of the acreage in long-term diversion would also return to field crops, but circumstances that have evolved since the land was committed to diversion could cause much of the remaining acreage to continue in other uses. One factor working against a return to field crops is the existing scarcity of a joint resource such as irrigation water. It could prove more profitable to retain some of the cropland in uses requiring little or no irrigation.

PRODUCTIVITY OF DIVERTED CROPLAND

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INTRODUCTION

Land withdrawal provisions have been an integral part of farm programs since the passage of the Agricultural Adjustment Act of 1933. The purpose of these provisions is to curtail land as a factor of production and reduce total output from U.S. farms. In 1966, nearly 63 million acres of cropland were not being used for production because of diversion under Government programs. This amounted to about 19 percent of the total land allocated for crops.

Acreage diverted is usually the marginal land on each farm participating in the programs. Some of the land is diverted because yields are lowest. Other land is diverted because production costs are high due to such factors as small, steep, or irregularly shaped fields, great distance from the farmstead, and high fertilizer requirements. Thus, for a given area or region, the diverted acreage is expected to be somewhat less productive than the acreage in crops.

But just how productive would this large diverted acreage be if it were returned to cultivation? This is a critical question for those concerned with future food and fiber needs and our capacity to meet them.

In estimating the future requirements for farm products and the potential acreage available to meet these requirements, assumptions must be made regarding the productivity of the cropland that has been out of production. Currently, estimates are being made assuming potential yields on diverted acres ranging from 25 percent to 90 percent of the yields on land now in production.1/ A dependable estimate is needed.

The present study developed an estimate of relative productivity by comparing the average productivity per acre of cropland diverted in 1966 with the average productivity of cropland in production. In making this estimate, we considered two sources of variation: (a) An intrafarm differential, which exists because fields within a farm have different levels of productivity and (b) an interfarm (or interlocation) differential, because the general level of productivity changes from one area to the next and because the proportion of cropland diverted may differ by area. Analytic methods were developed to capture both effects. However, the analysis could reflect the intrafarm effect only to the extent that data were available to measure it.

1/ See, for instance, Policies Affecting Rural People. N.C. State Univ. and the Center for Agricultural and Economic Development, Iowa State Univ., April 1966, pp. 2 and 20; also Foreign Agriculture, U.S. Dept. Agr., For. Agr. Serv., April 25, 1966, p.6.

The main source of data used in analyzing the intrafarm effect was contained in the National Conservation Needs Inventory. This inventory was updated in a national survey by the U.S. Department of Agriculture under the leadership of the Soil Conservation Service. The survey obtained fairly detailed data on land use. Each land use was cross-classified with the standard land-capability classifications of the Soil Conservation Service. A sample was statistically selected, and the data obtained were later expanded to represent total acreage in the National Inventory. Since data on individual farms were not available, county summary tables in the expanded data were used for the first part of this study in which yield per acre of the land in diversion was estimated from a model based on yield per acre of the land in production.[2]

Projected yields for several field crops weighted by the acreage of each crop were used as the objective measure of the potential productivity of each county.[3] A set of associated variables was then correlated with the yield index through multiple regression analysis, and the resulting parameters served in making yield estimates for fields diverted in 1966.

The decision on what particular field to divert is an intrafarm one; that is, the field to be diverted is compared with other fields on the same farm only. The ratios developed in this study, however, represent an average ratio for all intrafarm decisions at the county level. (A productivity differential ratio, say, of 0.95 indicates that the diverted fields are 95 percent as productive as the cropped fields for the county as a whole.) In turn, the ratio developed for the county acts as a proxy for the applicable intrafarm ratio.

It should be pointed out that the ratio developed here--productivity of diverted over nondiverted acres--reflects only those factors which SCS soil classifiers normally consider. Certain factors which can contribute considerably to differences in productivity of fields may go undetected in the normal process of classifying land. Although some of these factors are discussed later in this report, no objective estimate was made of their probable impact since supporting information was unavailable.

A second analysis was employed to estimate the location effect of the retired acres. Potential production per acre varies directly with projected yields per harvested acre, and yields, in turn, vary with location. Since the proportion of diverted-to-harvested acres also varies by location, it was necessary to deal with appropriate subdivisions of the total growing area. Simply multiplying total U.S. diverted acres by U.S. average projected yield would produce an incorrect estimate of aggregate production. This estimate would be too high if diverted acres were concentrated more heavily in the lower yielding locations and too low if the opposite conditions held.

Besides land, other important production factors are fertilizer, weed control, irrigation, labor, operating capital, and management ability. A limitation on any of these factors will restrict production. And as additional land is brought into production, the probability of limitations developing among other factors increases. This study measures only the relative quality of land retired.

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[2] The expanded data used here are subject to adjustment and may not be the final figures published in the Inventory.

[3] Projected yields are based on the historical yields of corn, wheat, barley, grain sorghum, and cotton for the most recent 5-year period, adjusted for trend.

Nature of Data for Intrafarm Analysis

Virtually all field examinations that were made for the National Conservation Needs Inventory occurred during 1966. Field data reflected conditions and principal crops or uses at that time. In addition, all data in a sample area were for the same crop year.

Major land-use groupings in the inventory included cropland, pasture and range, forest, and other land. Cropland was further classified into the 13 subdivisions described in appendix A. For this study, the most important categories are those dealing with field crops and with diverted and idle acres.

Acreages for each use listed in appendix A were further subclassified by their capability for agriculture.4/ Under this system, there were eight land-capability classes: I, II, and III which were suitable for regular cultivation and a wide range of other uses; IV which was marginal for cultivation; and V through VIII which were generally suitable for noncropland uses only.

Land-capability classification 5/ is one of a number of interpretive groupings of soils made primarily for agriculture. As in all interpretive groupings, this classification begins with individual soil-mapping units. Arable soils are grouped by their potentialities and limitations for sustained production of the common cultivated crops that do not require specialized site conditioning or site treatment. Nonarable soils, those not suitable for longtime sustained use for cultivated crops, are grouped by their capability to produce permanent vegetation and by their risks of soil damage if mismanaged.

The land-use breakdown available under the broad category of "cropland" afforded an opportunity to compare land in cultivated crops with land in idle and conserving uses during 1966. Of the 13 land-use groupings in appendix A, groups 1, 2, and 3 include the crops we are primarily concerned with when dealing with cropland diversion programs. A productivity index based on these acres, along with the summer fallow acres in group 4, reflected the productivity of the land on which feed grains, wheat, cotton, and other crops were grown in 1966.

On the other hand, groups 8, 9, and 12 included acreage in 1966 diversion programs, both annual and long term. A productivity index based on these acres would reflect a measure of the productivity of the diverted acres.

Some diverted acres may be found in group 4, summer fallow in semiarid regions; they are considered to have the same productivity as the average of combined field crop acres for that county because summer fallow and crops use the same fields in alternate years.

The index developed for the diverted acres divided by the index for the field crop acres provided an estimate of relative productivity of land diverted during 1966 divided by acreage in crops during the same year.

4/ For general definitions of land-capability classes, see Basic Statistics of the National Inventory of Soil and Water Conservation Needs. U.S. Dept. Agr. Statis. Bul. No. 317, August 1962.

5/ Klingebiel, A.A. and P.H. Montgomery. Land-Capability Classification. U.S. Dept. Agr., Agr. Handb. 210, September 1961.

Selection of Study Counties

Data on land use by capability class were available for all U.S. counties. Since one-third of these counties had very small acreage under diversion during 1966, they were excluded from the study. The counties included had a minimum of 3,000 acres diverted under annual programs, and this acreage made up at least 1 percent of the total county area.

Acreage in long-term retirement was not directly considered in defining the study area. Significant concentrations of acreages in long-term retirement exist where common field crops are unimportant; consequently, such areas were excluded for our purpose. By considering annual diverted acres only, we restricted the study to those areas that commonly grow feed grains, wheat, or cotton. The 1,977 qualifying counties contained about 96 percent of all acreage diverted under the 1966 feed grain, wheat, and cotton programs. They also contained about 88 percent of the land in long-term retirement under Conservation Reserve and Cropland Adjustment programs. Acreage in long-term diversion approximated one-fourth of the total acreage in diversion.

Since we did not have the resources to examine all 1,977 counties, a random sample of 300 counties was selected. The sampling problem was complicated by the fact that applicable units of observation varied widely--from just over 3,000 acres in some counties to nearly 200,000 acres in others. Allowance had to be made for this wide range.

The technique for selecting the 300 counties was to sample with probability proportional to size--a higher probability was assigned to large units when the sample was being drawn. The first sample county was chosen by drawing a number at random; a constant sampling interval (of diverted acres) was then used to select the remaining counties. Two hundred and ninety-nine successive increments of 151,700 were added to the number drawn until the total of 45,511,000 diverted acres was exhausted. The counties in which the 300 cumulative acreages fell were selected as the 300 sample units to observe. Figure 1 shows the regional distribution of the counties qualifying for study and the 300 counties selected.

The tally was made in the 300 counties to obtain the acreage in each of the eight land classes. Percentages of land by land class and by land-use groupings are shown in table 1. The first column (land-use groups 1 through 4) had a higher proportion in land classes I and II; the second column (land-use groups 8, 9, and 12) had a higher proportion in the remaining land classes.

AREAS QUALIFYING FOR STUDY AND SAMPLE COUNTIES SELECTED

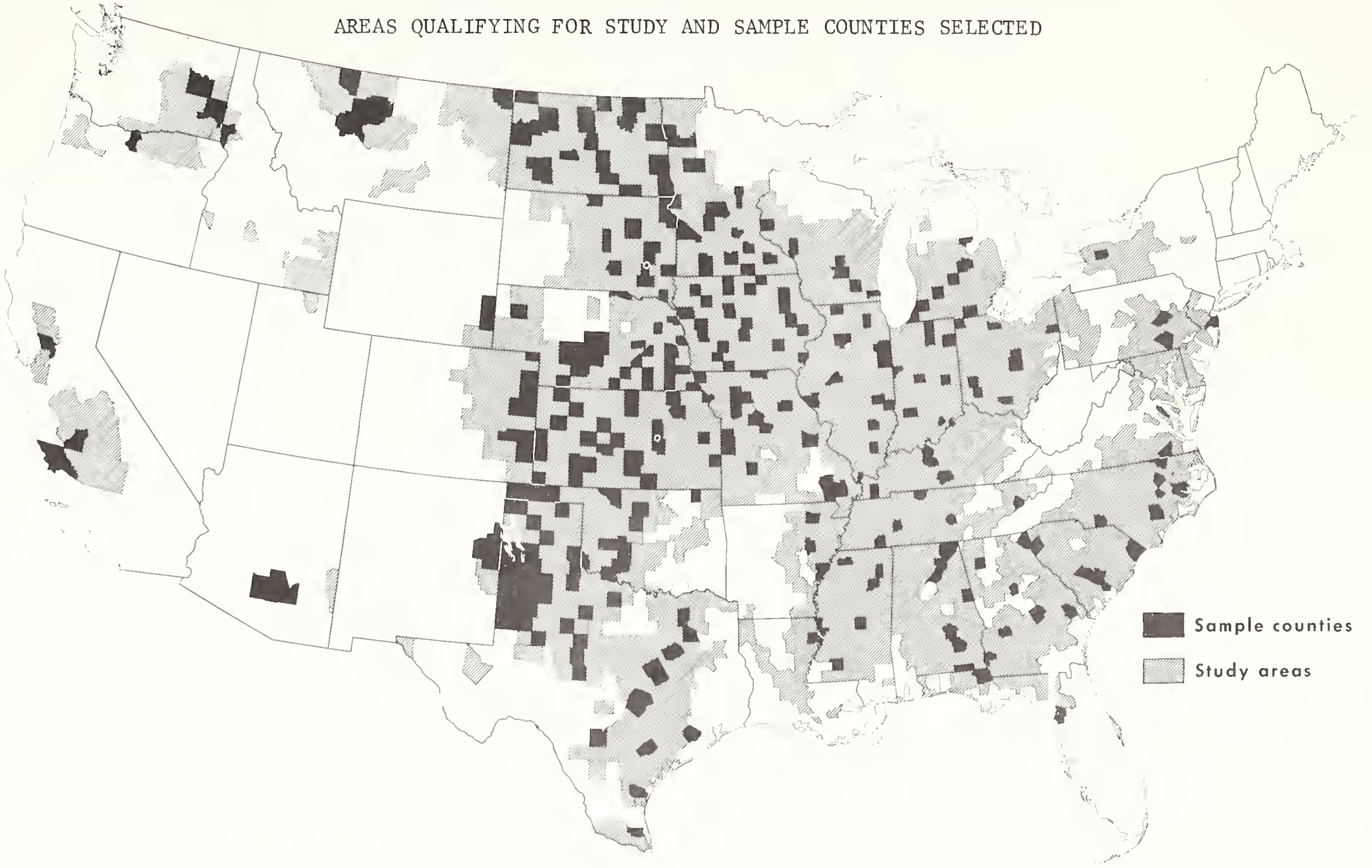

Figure 1

Table 1.--Percentages of land by land class and by land-use groupings, 300 U.S. counties, 1966

Land class	Land-use groupings	
	Field crop plus summer fallow acres (land-use groups 1-4)	Diverted and idle acres (land-use groups 8, 9, and 12)
	Percent	Percent
I	9.0	5.8
II	48.5	38.4
III	30.6	32.8
IV	8.7	14.5
V	.3	.3
VI	2.3	6.6
VII	.5	1.4
VIII	.1	.2
Total	100.0	100.0

ANALYTIC PROCEDURE

Before comparing the productive capacities of land, we needed to develop a yardstick which could measure productivity differences. In the present study, the "projected yields" employed by the Agricultural Stabilization and Conservation Service in determining diversion and price-support payments were used in building a composite index of productivity. 6/ This index was intended to reflect the capability of land to produce the common field crops.

Corn, wheat, sorghum, barley, and cotton were the only crops considered. Projected yield data by county were available for each of these crops. State crop acreages for 1961-65 determined the weights assigned to each crop in developing the productivity index for a particular county. The relative yield used to build the index was the county-U.S. projected yield ratio.

The index calculated by the above process serves as a simple objective measure that reflects the productive capacity of a county. But we know that many factors influence the productivity of a given tract or a county as a whole. On this basis, a search for appropriate variables was undertaken to develop a mathematical relationship between the calculated productivity index and a number of factors that help determine the level of productivity. It was recognized that only a statistical relationship could be obtained since the variables employed are not always the most relevant nor the most accurately measured. In addition, some pertinent variables are often unavailable or unmeasurable.

6/ Projected yields for the counties were determined from data adjusted for consistency with similarly established U.S. average projected yields; the distribution employed reflected a recent 5-year average in each county.

There were two phases to the intrafarm analysis. Phase I developed a relationship between productivity of land in common field crops and factors affecting such productivity. In phase II, this relationship was used as the model for predicting the productivity of diverted acres.

The statistical function employed takes the general form--

$$Y = f(X_1, X_2, \dots X_k, X_{k+1}, \dots X_n) + u$$

where Y, the dependent variable, is the calculated productivity index; X_1 to X_k represent the continuous independent variables; X_{k+1} to X_n represent one or more sets of discrete independent variables; and u represents the many nonspecified, nonmeasured variables. The analytic process is discussed further in appendix B.

Data pertaining to the 300 sample counties were fitted to the above regression equation. The independent variable side of the equation includes as variants the proportions of county field crop acreages in each of the eight standard SCS classes. A number of additional independent variables were also specified in the equation; data for these were obtained from the 1964 Census of Agriculture and other sources. The variables and the forms in which they were considered in the preliminary examination are discussed in appendix C. Most of these variables were retained in some form in the final regression model.

Using the completely specified equation, we were able to generate a set of coefficients in the final model.[7] These coefficients and the specifications developed in phase I were used as the model for the phase II analysis, in which the resulting predictive equation was solved to estimate the relative production potential of the diverted acres.

In several sample counties, no acreage was recorded for land-use groups 8, 9, or 12 in the inventory. Fallowing is a common practice in most of these counties; therefore, the diverted acres were assumed to be included under group 4, the summer fallow acres. The relative productivity between diverted acres on summer fallow and field crop acres was assumed to be "one" because summer fallow tends to have the same productivity as the fields in crops where fallowing is part of a regular rotation. The relative productivity assumed for all other sample counties was the ratio expressed by the phase II index over the phase I index.

The sample had been drawn so that each ratio stood for an equal number of acres diverted annually. That means the 300 productivity differential ratios could be averaged and the resulting average ratio used as the basis for estimating productivity of total land that had been out of production. The estimate for the entire Nation required an average of all 300 ratios. For any subportion of the Nation, the estimate was made by averaging the ratios of sample counties within the defined subregion.

There was still another aspect to consider when predicting aggregate production from diverted acres--the location effect. The reason is that the proportion of diverted-to-harvested acres was not constant from one location to the next. In other words, different farms and different areas diverted varying proportions of land that was normally devoted to feed grains, wheat, or cotton. Therefore, the total area must be subdivided to reflect, as much as possible, the different proportions which applied.

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[7] The coefficients represent the weights assigned each independent variable to obtain the best estimate of the dependent variable.

The State was the unit adopted for the breakdown because it was the smallest subdivision for which 1966 harvested acreages were available. The intracounty effect, which was assumed to reflect the intrafarm effect, was added to the differential attributed to the interstate location effect to measure the total difference.

ANALYSIS OF THE INTRAFARM EFFECT

Phase I

All the "variables for preliminary examination" discussed in appendix C were considered in a single regression equation. A number of successive computer runs were made, each testing a slightly different set of specifications.

The dependent variable, the productivity index calculated for each of the 300 sample counties, was the same throughout all phase I runs. On the independent variable side, the land class variants, described and designated as X_1 through X_6 in appendix C, were also specified the same way in all successive regression runs. Each of the six variables reflected the percentage of total land in a particular land class. The land referred to in this phase I analysis was the field crop acres covered under cropland subdivisions 1 through 4 (see appendix A).

Some of the other independent variables entering into the equation were alternately tested in several computer runs. Generally, that variable which contributed most to "regression effects" was the one selected for the final regression model. For example, in the process of selecting the preferred regionality variable, the effect of the 20 SCS land-resource regions for the United States (see appendix C) was compared with the effect of the nine general farming regions developed for this analysis. These resource regions consistently explained about 4 percent more variability in the productivity index than the general farming regions; consequently, the land-resource set was chosen to represent regional differences in the final regression model.

Some variables with a theoretical basis for explaining fluctuations in the productivity index were left out of the final model when test runs showed that they contributed very little toward reducing the residual variance. The effects of two closely related variables--precipitation available to growing crops and summer fallow as a percentage of total field crop acreage--were found to be statistically nonsignificant. The likely explanation was that the two offset each other--the proportion of summer fallow increased as available precipitation decreased. In the final equation, the precipitation variable was retained for only one region, the Corn Belt, where summer fallow was not a variable and where, as a result, precipitation in the growing season had a significant effect on the productivity index.

The variables considered in the phase I analysis, the functional forms in which they were tested, and the form in which the final variables were retained are discussed in detail in appendix D. The appendix also describes the steps taken to arrive at the final equation, and indicates certain references to support the analytic methods used.

The final regression equation was--

$$\begin{aligned}
Y_c = 15{,}204.60 &- \underset{(5.01)}{8.53}X_1^{*} - \underset{(4.96)}{7.99}X_2^{*} - \underset{(4.98)}{9.41}X_3^{**} \\
&- \underset{(5.05)}{9.44}X_4^{*} - \underset{(6.16)}{12.68}X_5^{**} + \underset{(0.65)}{1.10}X_7^{*} + \underset{(0.75)}{3.17}X_8^{**} \\
&- \underset{(0.59)}{2.79}X_{10}^{**} + \underset{(0.05)}{0.34}X_{11}^{**} + \underset{(0.03)}{0.26}X_{12}^{**} + \underset{(753.60)}{4{,}846.33}X_{14}^{**} \\
&+ \underset{(829.83)}{1{,}877.54}X_{15}^{**} - \underset{(543.85)}{149.51}X_{17} - \underset{(330.32)}{569.31}X_{18}^{*} - \underset{(790.52)}{1{,}257.69}X_{19}^{*} \\
&- \underset{(580.78)}{1{,}750.04}X_{20}^{**} - \underset{(662.55)}{243.47}X_{21} + \underset{(518.68)}{2{,}262.91}X_{22}^{**} - \underset{(1{,}542.64)}{2{,}764.38}X_{23}^{*} \\
&- \underset{(539.11)}{2{,}007.56}X_{24}^{**} + \underset{(775.01)}{1{,}532.94}X_{25}^{**} - \underset{(587.09)}{2{,}956.06}X_{26}^{**} + \underset{(1{,}272.04)}{2{,}279.40}X_{27}^{*} \\
&+ \underset{(742.33)}{350.60}X_{28} - \underset{(685.74)}{2{,}395.50}X_{29}^{**} + \underset{(13.60)}{35.71}X_{30}^{**}
\end{aligned}$$

where the single asterisk indicates significance at the 5-percent probability level and the double asterisk, at the 1-percent probability level. Each number in parentheses is the standard error of the coefficient under which it appears. The coefficient of multiple determination, R^2, was 0.7813; the adjusted coefficient, $\bar{R}^2$, was 0.7604.

Representation in the above formula is as follows:

Y_c = the productivity index calculated for each county;

X_1 through X_5 = the percentage of land in the several land classes, omitting X_6--the percentage in land classes VII and VIII;

X_7 and X_8 = the percentage of 1966 annual diversion which was diverted from feed grains and wheat, respectively (omitting X_9, the percentage of diversion from cotton);

X_{10} = long-term diversion as a percentage of total diversion;

X_{11} = irrigated acreage as a percentage of cropland harvested;

X_{12} = rate of fertilizer application;

X_{14} through X_{29} = a dummy variable set representing each of the regions B, C, G through P, and R to T in figure 4 (omitting X_{16}, region F); and

X_{30} = a test of the effect of June, July, and August precipitation on productivity in region M.

The results indicated that 76 percent of the observed variation in Y_c was explained by the variables X_1 through X_{30}, using the functional forms specified for the final equation.

Phase II

In the model developed by the preceding analysis, an attempt was made to control the effects of regional influences and other important factors. Nevertheless, some other pertinent effects could not be taken into account where information was neither available nor amenable for direct incorporation into the final phase I model. The tentative effects of those factors that were not measured or specified are discussed later in this report.

Assuming the same application of fertilizer, irrigation, and other practices on diverted as on field crop acres, we found that any inherent differences in the land could be detected through the land-capability classifications. It was on this basis that an estimate of diverted acre productivity was derived for each of the sample counties.

The model developed in phase I was used in phase II to estimate a productivity index for the diverted acres. To obtain these estimates, we made the statistic $\bar{Y}$ (an index of average best fit, rather than Y_c, the actual calculated index) the dependent variable for the phase II operation. The only change among the independent variables was to introduce X_1' through X_5' to replace X_1 through X_5 used in phase I. The "prime" variable group (X') represented the proportions of land in the eight land classes, including the diverted acres; the "nonprime" group represented similar proportions of land, including the common field crops.

The results indicate that the intrafarm effect contributed comparatively little to differences between the productivity of diverted acreage and that of field crop acreage, at least insofar as the inherent quality of the land was concerned. Table 2 gives ratios of average relative productivity for the two categories by land-resource region and for the United States as a whole. The proportions are referred to as intrafarm productivity differential ratios. The average ratio for all regions suggests that the diverted acres had a production potential which was only 3.4 percent below that of land producing common field crops in 1966; the range was from about 1 percent less productive in the Lake States to about 7 percent in the Southwest States.

These results are similar to Vermeer's findings in his study of the 1961 feed grain program. Vermeer used two approaches to estimate the difference in yields of fields growing corn or grain sorghum in 1961 and fields with acreage diverted from these two crops. His first set of estimates ranged from no difference in southern Iowa to a 7-percent difference on the nonirrigated acreage of southwestern Kansas. In his second approach, the farmers estimated that their yields on the diverted acres would average 1 to 5 percent lower than actual yields obtained in 1961.8/

8/ Vermeer, James. An Economic Appraisal of the 1961 Feed Grain Program. U.S. Dept. Agr., Agr. Econ. Rpt. 38, June 1963.

Table 2.--Average relative productivity for various land-resource regions, 300 U.S. counties, 1966

Land-resource region	Observations	Average productivity differential ratio 1/
	Number	
B	4	.946
C and D	4	.932
F	28	.946
G	10	.966
H	67	.951
I	3	.969
J	8	.969
K	5	.985
L	12	.989
M	98	.981
N	17	.982
O	7	.964
P	25	.952
R and S	6	.968
T	6	.955
Total, all regions	300	.966

1/ Productivity index of diverted acres divided by productivity index of field crop acres.

ANALYSIS OF THE LOCATION EFFECT

A further investigation was made to determine what impact the location of the diverted acres might have on potential aggregate production. If acres diverted were distributed in the same proportion as acres harvested, the location effect would be nil. Any other distribution would produce a location effect which either added to or subtracted from the productivity differential attributed to the intrafarm effect. An analysis was undertaken to measure the extent of the location effect.

Acreage harvested in 1966 and acreage diverted that year under the annual diversion program were used to compute ratios of diverted acres to harvested acres for each State. As shown in figure 2, the ratios varied significantly.

Figure 2 also shows that the Western States had a low ratio of diverted-to-harvested acres along with a high productivity index.9/ The Southeast States, on the other hand, had a high ratio and a low productivity index. The Northeast and North Central States assumed an intermediate position, while the Northern Plains and the Middle Plains States had both a low ratio and a low productivity index.

In 1966, a greater proportion of diversion was associated with those States that had a low productivity per acre. One method of determining the effect of location on productivity was to estimate the additional production of the several crops that might have been obtained from the annual diverted acres. Three different sets of assumptions were used for these diverted acres. The first assumption was that neither an intrafarm effect nor a location effect prevailed. In this case, the expected increase

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9/ A notable exception is New Mexico where average productivity was boosted by irrigation, but diverted acres probably formed most of the State's dryland.

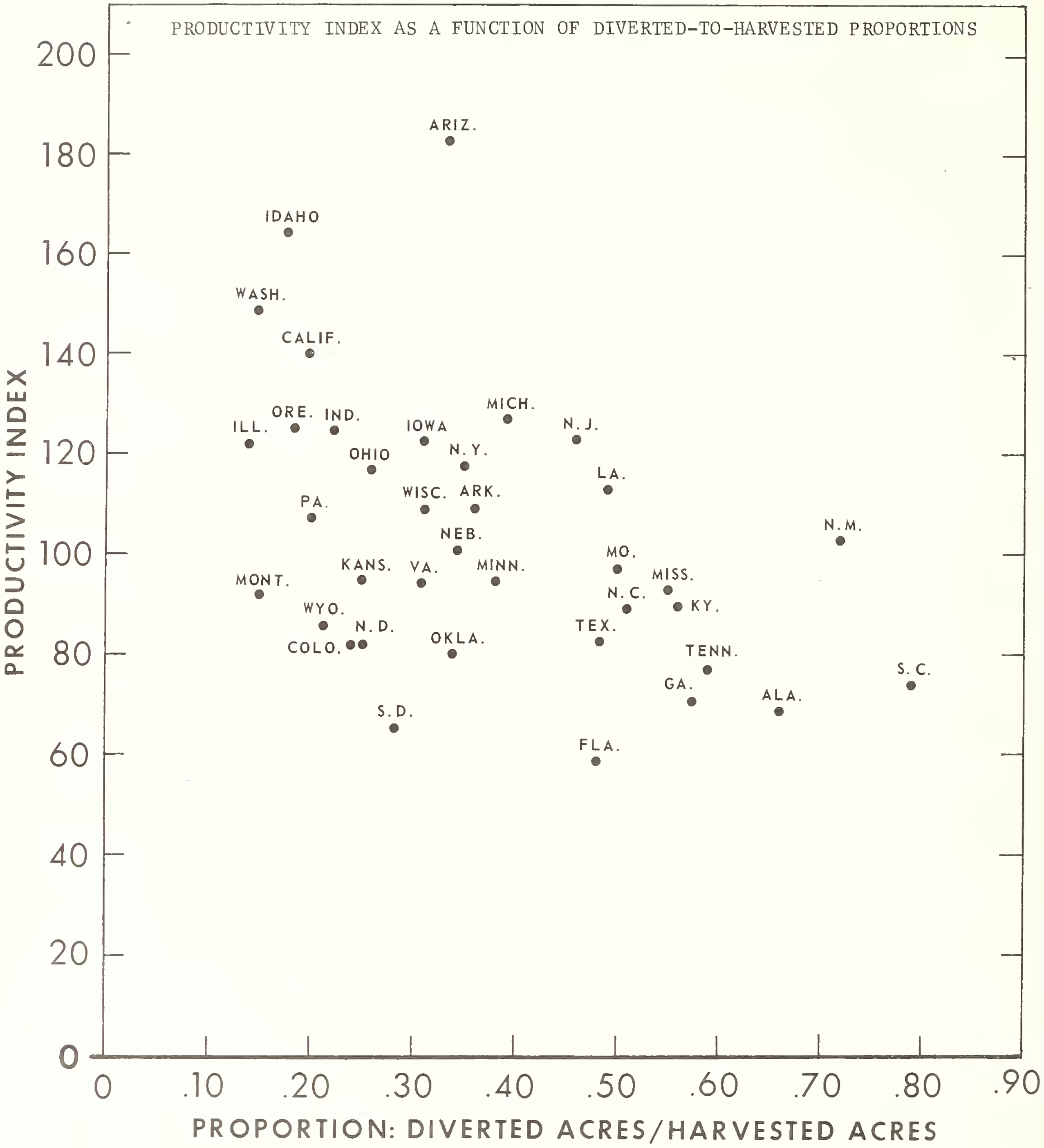
PRODUCTIVITY INDEX AS A FUNCTION OF DIVERTED-TO-HARVESTED PROPORTIONS
PRODUCTIVITY INDEX
PROPORTION: DIVERTED ACRES/HARVESTED ACRES
0
20
40
60
80
100
120
140
160
180
200
0
.10
.20
.30
.40
.50
.60
.70
.80
.90
ARIZ.
IDAHO
WASH.
CALIF.
ILL.
ORE.
IND.
IOWA
MICH.
N. J.
OHIO
N. Y.
LA.
PA.
WISC.
ARK.
NEB.
N. M.
MONT.
KANS.
VA.
MINN.
MO.
MISS.
N. C.
KY.
WYO.
N. D.
COLO.
OKLA.
TEX.
TENN.
GA.
ALA.
S. C.
S. D.
FLA.

Figure 2

ranged from 15 percent more wheat to 44 percent more cotton than the total actually projected for 1966. The ratio of diverted acres to harvested acres for a given crop times 100 gives the percentage increase of that crop. The same percentage of crop abandonment that occurred on fields planted in 1966 was applied to the diverted fields.

The second assumption allowed for an intrafarm productivity differential but still no location effect. This brought with it a small reduction in the percentage increase associated with the first assumption. A greater reduction was effected by the third assumption which allowed for both an intrafarm and a location effect. Table 3 gives the percentage increase in each crop that might have been obtained in 1966 if the diverted fields had been planted to the "designated diverted crop."

Table 4 gives the intrafarm and interlocation proportions of total difference in productivity of diverted land and cropped land. Except for wheat, the location effect was greater than the intrafarm effect. Apparently, the acres designated as diverted from wheat were distributed in nearly the same proportion as acres of whéat harvested. For the other four crops, the diverted acres were concentrated more heavily in areas with smaller yields.

Table 3.--Estimated additional production of several crops that might have been obtained from 1966 annual diverted acres, with different sets of assumptions

Assumptions concerning the diverted acres	Percentage increase in the production of--				
	Corn	Wheat	Grain sorghum	Barley	Cotton
1. No allowance for intrafarm effect or location effect	34.95	15.17	42.00	32.33	44.06
2. Allowance for intrafarm productivity differential but not for location effect	33.96	14.56	40.27	30.76	42.11
3. Allowance for both an intrafarm productivity differential and an interstate location effect	30.43	14.44	38.23	28.94	38.08

Table 4.--Relative contributions of intrafarm and interlocation effects to reduced productivity on the diverted acres

Effect contributing to reduced productivity	Proportion of reduced productivity on fields whose "designated diverted crop" was--				
	Corn	Wheat	Grain sorghum	Barley	Cotton
Intrafarm effect	.219	.836	.459	.463	.326
Interlocation effect	.781	.164	.541	.537	.674
Total effect	1.000	1.000	1.000	1.000	1.000

EVALUATION OF THE RESULTS

The intrafarm and interlocation effects from the preceding analysis were added to give a combined productivity differential. Results showed that acres diverted from wheat were about 95 percent as productive, on the average, as acres actually producing wheat in 1966. For grain sorghum, the parallel figure was 90 percent; for barley, 88 percent; for corn, 85 percent; for cotton, 84 percent.

We know, however, that the total intrafarm effect was larger than indicated by the formal analysis. The SCS land classifications, the basis for present estimates, do not incorporate certain factors which may contribute significantly to productivity differences. The selection of fields for diversion will be influenced by many factors, including some not directly related to the inherent productive capacity of land.

The selection of land to divert is not usually determined by the marginal acre of cropland; rather, the choice is determined by the marginal field eligible for diversion. Regulations limit the signup of tracts or fields below a minimum size. Other things equal, the field selected will be the one promising least net return per unit of land.

Significant differences in productivity may exist on fields with a very similar quality of land. The number of acres actually in production may not be the same for two fields which the record shows to be of equal size. Of two 40-acre tracts, one may have 5 percent fewer cultivated acres because 2 acres of grassed waterway run through it. Similarly, one field may have more potholes which are too wet to seed in the spring and may therefore end up with fewer seeded acres.

Still another field may gradually be losing some of its productivity due to an alkaline condition invading its perimeter. Such a condition could be caused by a nearby slough or irrigation canal. A consequent high water table may force the salts of the subsoil so close to the surface that common field crops cannot grow in the high pH level.

Years of experience with a given farming operation reveal some peculiarities about certain fields--peculiarities which may not be detected in the normal process of land classification. For example, over the years, one field may have been demonstrating greater response than another to a given application of fertilizer or irrigation water.

All of these factors could not be considered in the formal analysis of this study. Over fairly large areas, they may occur very infrequently and contribute little toward differentiating fields. The more uniform areas, often the more productive and more solidly planted areas, could come under this classification. On the other hand, these same factors may occur frequently and cause substantial differences among the fields where heterogeneous conditions prevail.

No attempt was made to estimate the actual impact of these extra factors. However, it is believed that their net effect might not exceed the effect of the formal intrafarm analysis. After considering all sources of variation, the production of the diverted acreage as a percentage of the acreage in production was estimated at 90 percent for wheat, 85 percent for grain sorghum, 83 percent for barley, 82 percent for corn, and 80 percent for cotton. The assumption was made that annual diverted acres would return to the "designated" crops from which they were diverted. It was assumed further that land coming out of long-term retirement would grow these five crops in the same proportion specified for annual diversion.

RETURN OF DIVERTED ACRES TO PRODUCTION

Under conditions favoring production, it is reasonable to assume that all annual diverted acres would return to production. Under a favorable price incentive, even the long-term diverted acres would return to crop production. But the price situation that is more apt to prevail could cause a significant proportion of these acreages to continue in other uses. Land once planted to trees is not likely to return to field crops. Some parcels of land that were seeded to grasses or legumes may continue in hay and pasture after the land becomes eligible for return to field crops. Use for hay and pasture rather than for crops could better fit a new set of circumstances that may have evolved for the owner while a field was in long-term diversion. For instance, he could have acquired an off-farm job in the interim period and would now prefer a land use whose operations demand less of his time. Or he may have divested himself of the machinery that went with his former cropping practices.

Of course, the new producer need not be the same person who previously operated the field now returning to production. Although the price incentive for growing field crops may be insufficient for the former operator who has acquired new interests, it may be an inducement to a new operator who needs more acres to run an efficient farm unit. Also, a field which is "high cost" to one operator because it is far from his main operation may lie close to a potential new operator. The latter could buy or rent the production resources of this field.

Land coming out of retirement is apt to follow an ordered sequence. If economic criteria determined the order in which the fields went into diversion programs, the opposite order would tend to apply in the way they came out. The better quality fields would come out first, followed by fields of progressively lesser quality. Some land, as indicated above, would likely continue in alternative uses and would not return to field crops.

One factor that could strongly deter the return of all fields on a given farm to field crops would be an absolute limit to a given resource. For example, suppose there was not enough water for adequate irrigation of all cropland on a farm. Then if some acres were diverted, the remaining acres would receive the benefit of extra irrigation water. Thus, it could be more profitable to maintain some of the cropland in uses that require little irrigation.

APPENDIX A

Cropland Subdivisions

(1) Corn and sorghums - Broadcast or grown in rows for all purposes (grain, silage, or forage).

(2) All other row crops - All cultivated crops grown in rows except corn and sorghum. Include cotton, tobacco, peanuts, soybeans, sugarcane, vegetables, potatoes, and strawberries.

(3) Close-grown field crops - Small grains and other close seeded crops not usually grown in rows and tilled. Include wheat, oats, barley, rice, rye, and crops used for temporary hay or pasture.

(4) Summer fallow - Fallow cropland in semiarid areas.

(5) Total field crops - Sum of (1) through (4).

(6) Rotation hay and pasture - Grasses and legumes used for hay or pasture as part of the crop rotation.

(7) Hayland - Land permanently used for forage including--

- (a) Land on which the stand is improved occasionally by preparing seedbeds or applying other measures.
- (b) Land from which grasses and legumes are harvested for hay or seed and then pastured or left to grow forage.
- (c) Wild hay.
- (d) Mountain meadows in Western States.

(8) Conservation use only - Grasses, legumes, or small grains grown on cropland but not harvested or pastured; all open acreage diverted from other crops under Federal programs except that in summer fallow; similar land not under Federal programs. Does not include land defined as "forest land."

(9) Temporarily idle cropland - Idle land used for one of the purposes defined in (1) through (7) at least once during the 3 years before inspection.

(10) Total tillage rotation - Sum of (5) through (9).

(11) Orchards, vineyards, and bush fruit - Fruit and nut orchards even if intertilled or pastured. Includes cranberry bogs, bush fruit, blueberries, and similar fruit crops.

(12) Open land formerly cropped - Same as (9) except that the land--

- (a) Has been idle more than 3 years.
- (b) Is not purposely being converted to another use.

(13) Total cropland - Sum of (10), (11), and (12).

APPENDIX B

The Analytic Process for the Intrafarm Analysis

The analytic process can be portrayed in abstract form with two equations. The equation used in phase I is as follows:

$$Y_c = a + b_1X_1 + \ldots + B_8X_8 + b_9X_9 + \ldots + b_kX_k + b_{k+1}\ X_{k+1} + \ldots + b_nX_n$$

where Y_c is the productivity index calculated for land used in 1966 for crop production in each county; X_1 through X_8 are the proportions of total acres in the eight specified land classes; X_9 through X_k are other continuous variables; X_{k+1} through X_n are the sets of discrete variables. The parameter estimates, a and the b_i's, are generated in this equation and serve again in the phase II equation. Variables employed for preliminary examination are described in appendix C.

In phase II, the model takes the following form:

$$a + b_1X_1' + \ldots + b_8X_8' + b_9X_9 + \ldots + b_kX_k + b_{k+1}\ X_{k+1} + \ldots\ b_nX_n = \hat{Y}$$

where X_1' through X_8' are the proportions in the several land classes of diverted and idle acres (land-use groups 8, 9, and 12 in appendix A); X_9 through X_n are the same input data applied in phase I; the a and b_i's are the same parameters generated in phase I. $\hat{Y}$ is the productivity index estimated for the acres in land-use groups 8, 9, and 12.

APPENDIX C

Variables for Preliminary Examination

Soil and climatic conditions usually rank among the most salient of explanatory variables in a study of land productivity. These conditions were closely observed by the Soil Conservation Service in classifying land capability for agriculture. A set of variables encompassing these classifications can form an important adjunct of independent variables to be considered.

Soil and climate effects were incorporated through a group of variables reflecting the acreage in each land class as a proportion of the total. The proportions in land classes V and VIII were so insignificant, on the average, that each was combined with another class: V with IV and VIII with VII. Six designations were specified for the equation: The proportion of acres in land classes I, II, and III as X_1, X_2, and X_3, respectively; the proportion in land classes IV and V as X_4; that in land class VI as X_5; and that in land classes VII and VIII as X_6.

Some of the variation attributable to climate and soil is not detected by the mere expedient of land classification. There is need for further categorization into groupings that follow different criteria, e.g., categories built up on a regional basis to reflect situations with similar cropping practices. Such situations may, up to a point, delimit regions with similar climates. Another pertinent classification with a regional basis might be one which reflects different resource situations.

Two regionality variables were considered in alternate regression runs in the form of dummy variable sets:

Set 1: General farming regions

Northeast
Southeast
Corn Belt
Midsouth
Northern Plains
Middle Plains
Southern Plains
Northwest
Southwest

Set 2: Land resource regions

B - Northwest wheat and range region
C - California subtropical fruit, truck, and specialty crop region
F - Northern Great Plains spring wheat region
G - Western Great Plains range and irrigated region
H - Central Great Plains winter wheat and range region
I - Southwestern plateaus and plains, range and cotton region
J - Southwestern prairies, cotton and forage region
K - Northern Lake States forest and forage region
L - Lake States fruit, truck, and dairy region
M - Central feed grains and livestock region
N - East and Central general farming and forest region
O - Mississippi Delta cotton and feed grains region
P - South Atlantic and Gulf Slope cash crop, forest and livestock region
R - Northeastern forage and forest region
S - Northern Atlantic Slope truck, fruit, and poultry region
T - Atlantic and Gulf Coast lowlands forest and truck crop region

Outlined in figure 3 are the farm production regions and in figure 4 the land resource regions. Both sets of regionality variables were specified as dummy variables in the regression model.

Both regional groups have a theoretical basis for being included as an explanatory factor. However, considerable parallel exists between the two sets of categories, and therefore only one set was specified in any given regression run. The set that contributed most to "explained variance" in the dependent variable was retained in the final analysis as the regionality variable.

Another variable specified in two alternative ways was one identifying counties by major diverted crop. The first specification employed was in terms of dummy variables. Counties were classified according to whether most of their diversion

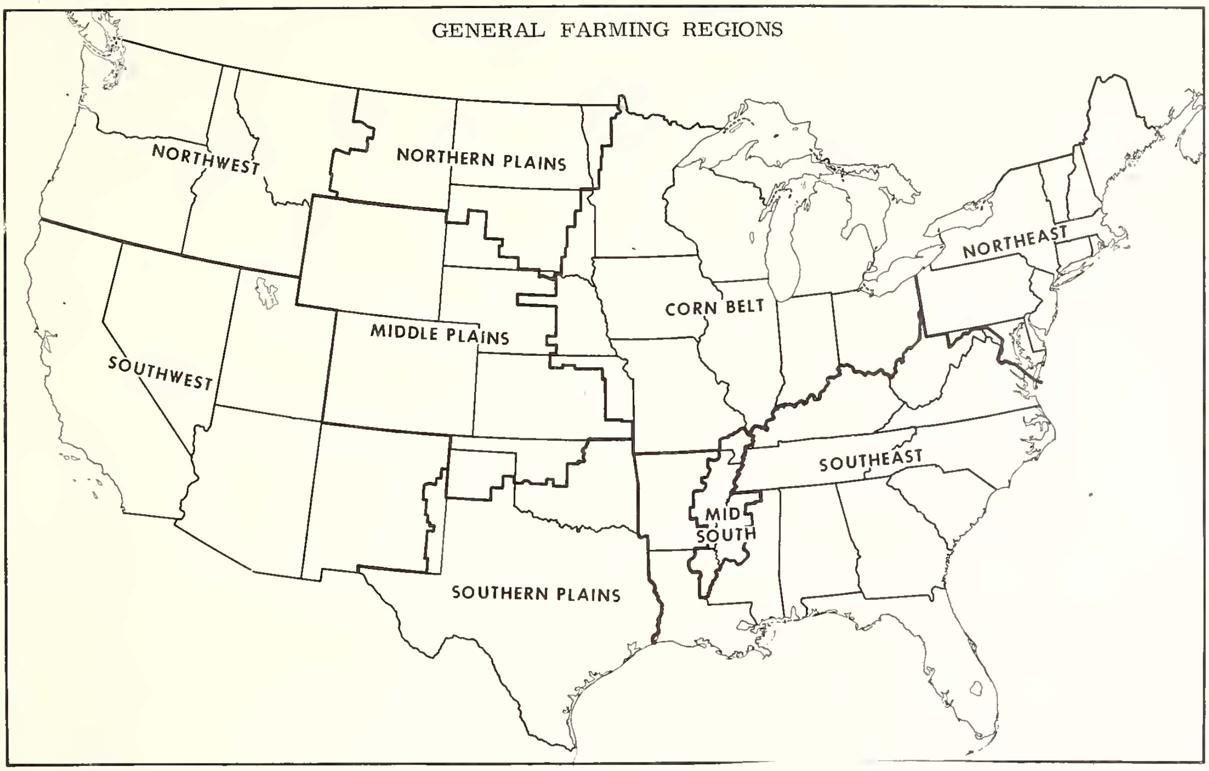

Figure 3

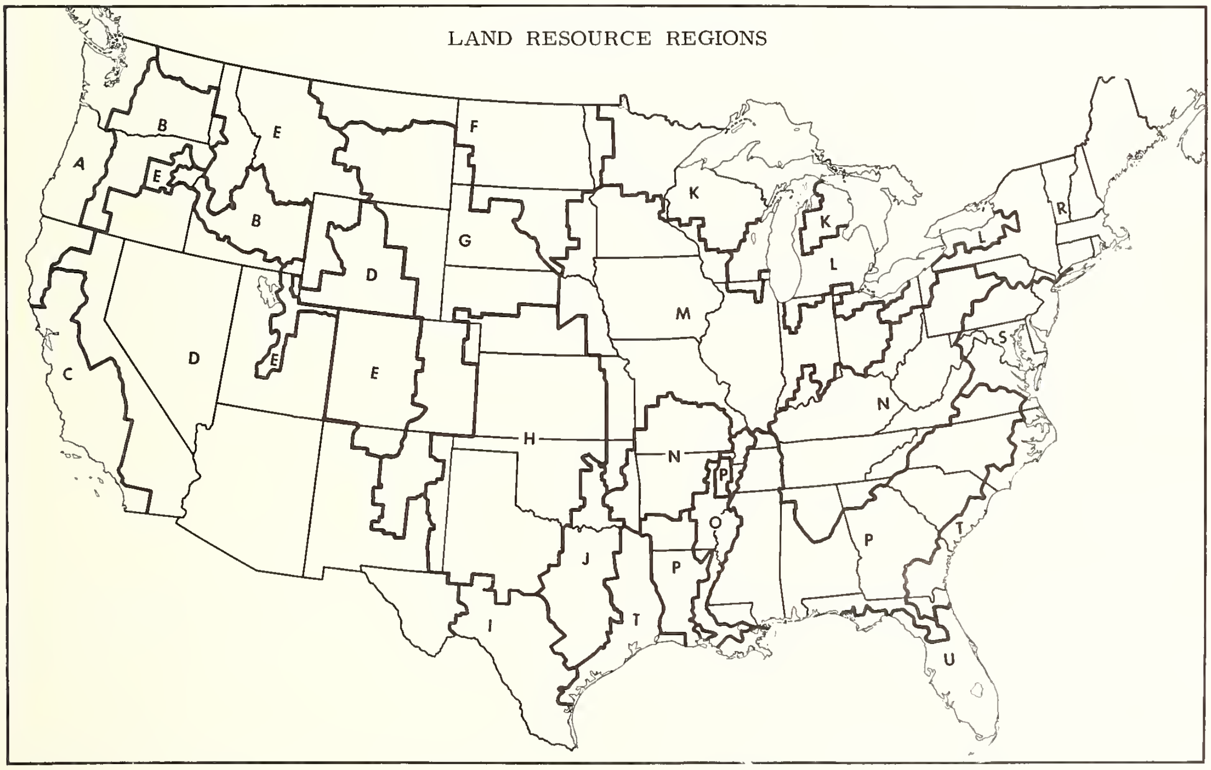

Figure 4

was from feed grains, wheat, or cotton. An alternative specification used an approach similar to that employed with land classes. The proportion of total diversion that each of the three categories formed was entered as a continuous variable. The specification chosen for the final analysis was that which contributed most to "regression effects."

Long-term diversion as a percentage of total diversion was considered a measure that could have a bearing on productivity. It was hypothesized that land in long-term diversion was less productive, on the average, than land in annual diversion. Hence, other things equal, an inverse relationship might be expected to exist between the productivity index and the percentage of long-term diversion.

Rate of fertilizer application is another factor which influences yields and consequently the productivity index. Based on pounds per acre of nitrogen, phosphate, and potassium applied in turn to corn, wheat, barley, sorghum, and cotton (made available through the 1964 Census of Agriculture), a weighted index was calculated. The 1961-65 State acreage of these five crops determined the weights assigned to each crop. It was expected that this fertilizer index would have a significant correlation with the productivity index.

In much of the area where field crops are extensively grown, moisture is a factor limiting greater productivity. Hence, a measure of precipitation available to the growing crops was specified as a variable. We used total precipitation for June, July, and August in the Corn Belt and precipitation for May, June, and July in the Northern Plains. Total annual precipitation was used in both the Southern Plains and the Western States.

Two processes which supplement the effects of available precipitation in the semiarid regions are summer fallowing and irrigation. In semiarid areas, therefore, two variables were added: (1) Summer fallow as a percentage of total field crop acreage and (2) irrigated cropland as a proportion of cropland harvested. The latter variable, although significant only in the semiarid regions, was specified to apply throughout the total study area.

In the initial regression runs, additivity was assumed among all independent variables. Tests were then made for possible interaction effects, and significant effects were taken into account. The final model then served as a predictive equation in phase II.

APPENDIX D

Description of the Phase I Analysis

Multiple regression analysis was employed, using the calculated productivity index as the dependent variable. The independent variables tested were considered relevant for capturing variance in the productivity index.

The land class variables designated X_1 through X_6 (see appendix C) were entered in the equation as continuous linear variables. Each variable represented the percentage of total field cropland in a designated land class.

The percentages making up variables X_1 through X_6 added up to 100 for any given observation, or county. Thus, if an attempt were made to correlate the productivity index with all six variables simultaneously, it would be impossible to solve the problem or it would give a spurious result.[10] If the variation in X_1 through X_5 had been held constant, there would not be any variation left in X_6.[11]

The variable dropped from the land class set for the present analysis was X_6--percentage of land in classes VII and VIII. The determination of which variable to drop is arbitrary, and any one of the other five variables could have been omitted instead.

A parallel problem existed in specifying sets of dummy variables. It was necessary to drop one class from each set so that estimates of regression parameters could be obtained from the remaining classes. If each class in a given set were forced into the equation, the system would become over-determined and a solution would be impossible. The class omitted became the "base" for comparison with other classes in the same set; the coefficient representing each retained class indicated the extent to which this class differed from the base (omitted) class.[12]

In the present analysis, the cotton category was omitted from a dummy variable set in which counties were classified whether most of their diversion was from feed grain, wheat, or cotton. Among the regionality variables, the Northern Plains States were selected as the classification to omit from the nine general farming regions developed for this analysis; the "F" region was the classification omitted from the 20 land resource regions delineated by the Soil Conservation Service. In each case, it was an arbitrary decision as to which category to omit. The general farming regions and land resource regions referred to here, are delineated in figures 3 and 4, appendix C. The remaining variables, whose influence on productivity was to be tested, were all specified as continuous linear variables.

In determining which regionality variable to select, we found that the land resource regions as a set consistently demonstrated greater regression effects than the general farming regions. In several regression runs, when the effects of several other variables were held constant, the "land resource" set consistently explained 4 to 5 percent more variability in productivity than the general farming set. Even when allowance was made for the seven additional degrees of freedom used up by the land resource group, it still explained nearly 4 percent more variability than the general farming group.13/

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[10] Mathematically, we say there is perfect linear multiple correlation among X_1 through X_6; any attempt to estimate the regression parameters will fail because of singularity in the moment matrix.

[11] For a discussion of this problem, see Ezekial, Mordecai and Fox, Karl A., Methods of Correlation and Regression Analysis, John Wiley & Sons, Inc., N.Y., 3rd edition, 1959, p.473.

[12] More complete information is found in Suits, Daniel B. "Use of Dummy Variables in Regression Equations." Jour. Amer. Statis. Assn., Vol. 52, December 1957, pp.548-551.

In determining the preferred specification for the "major diverted crop" variable, we tried the dummy variable form first. Neither the feed grain group nor the wheat group was significantly different at the 5-percent level from the omitted cotton group. This was a test to see if the average level of productivity was significantly different from one group to the next.

Then two additional variables were added to test if there was a significantly different slope in the productivity function among the three groups. This test used "percentage of diversion from the crop in question" as the independent variable. It was a test, in other words, to see if there was a significant interaction between "percentage of diversion" and "groups." Compared with the cotton group, the slope of the function for the wheat group was significantly different while that for the feed grain group was not.14/

Another regression was then run using an alternative specification in which the proportions of total diversion that feed grain, wheat, and cotton formed, were entered as continuous variables. The cotton variable was then dropped out of the equation so that a determinate solution of the system could be obtained. It turned out that the variables were significant for feed grains at the 5-percent level and for wheat at the 1-percent level. Together, these two variables had a slightly greater effect on explained variance than the four variables used in the first specification. Hence, the alternative specification was the one selected for the final model.

Two closely related variables--precipitation available to growing crops and summer fallow as a percentage of total field crop acreage--were then tested to see if they could add significantly to the regression effects produced by the other variables. Because these two factors were thought to be relevant only in the semiarid

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13/ The coefficient of multiple determination, R^2, measures the variance explained by the regression but does not allow for situations in which unequal numbers of variables are being compared in the two equations. Because a bias results from the unequal degrees of freedom, an adjusted coefficient of multiple determination, $\bar{R}^2$, was used to compensate for the difference in degrees of freedom. There is an exact functional relationship between R^2 and $\bar{R}^2$ since--

$$R^2 = 1 - \left[(1-R^2) \cdot \frac{N - 1}{N - P - 1} \right]$$

where N = number of observations and P = number of independent variables.

14/ This test was made with the aid of so-called interaction terms. These terms are a product of a continuous variable (in this case, the percentage of diversion from the crop in question) multiplied by a categorical variable (here, the major crop diverted). Of the three resulting interaction terms, the two pertaining to feed grains and wheat were specified in the equation and the cotton group was omitted. The latter group therefore became the "base" group for comparison with the other two terms. The coefficient associated with the "wheat" interaction term was positive and significant at the 5-percent level.

regions in the Western States, they were specified only in land resource regions B, F, G, and H. Neither "available precipitation" nor "the percentage of summer fallow" showed a significant effect.15/

Lack of correlation with the productivity index may be attributable to the offsetting effect in the two influences. Proceeding from east to west in regions F, G, and H, the available precipitation decreases as the percentage of summer fallow increases. This sequence is attended by a decrease in productivity per cropland acre, but productivity per planted or harvested acre does not change very much. The increasing proportion of summer fallow, as one proceeds west, brings with it a necessarily decreased proportion of cropland planted and harvested. Crops planted on summer fallow within these regions tend to yield about as well as crops on the continuously cropped land farther east. Since the positive effects of summer fallowing tended to offset the negative effects of lower precipitation, the variation in the productivity index was small for counties in regions B, F, G, and H. It is likely that either the precipitation or summer fallow variables would have shown a significant effect if the productivity index had been calculated on the basis of productivity per cropland acre rather than per harvested acre.

In region M, the Corn Belt, continuous cropping is a common practice and therefore summer fallow was not a variable. A precipitation variable combining the June, July, and August rainfalls in that region proved to be significant at the 1-percent level. Thus, it was incorporated in the final model as a variable for region M.

15/ The effect of a given influence can be tested for a particular region (as set apart from other regions) by following a procedure similar to the test for interaction effects (see footnote 14). The dummy variable set made up of land resource regions was multiplied by either "available precipitation" or "the percentage of summer fallow"; the two groups of joint variables were than alternatively specified in the equation. A "significant" coefficient would have indicated a substantial (precipitation or summer fallow) influence in the applicable region.

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